electrons in the region below 50 kev as compared to that predicted by the Fermi theory of beta-disintegration. Recently, Cook and Langer[2] investigated both the positron and negatron spectra from Cu^{64} over the entire energy region and found that both negatrons and positrons at low energies are too numerous to be accounted for by theory. Since the technical difficulties involved in the study of the beta-ray spectrum at very low energy are considerable, it is desirable to know how far the remaining discrepancies between experiment and theory at low energy can be reduced by improving experimental technique and employing a more rigorous Coulomb correction factor in interpreting the data.

The Columbia University solenoid β-ray spectrometer[3,4] was used in this investigation. In order to distinguish between electrons and positrons, a simple modified baffle system has been used and is found to transmit particles of one sign only, introducing no detectable scattering. The axis of the spectrometer is at least six feet away from any walls and is orientated along the earth's magnetic meridian. The vertical component of the earth's magnetic field is compensated by means of a pair of Thomson coils.

The radioactive Cu^{64} was prepared by intense deuteron bombardment of copper in the Columbia cyclotron. In carrying out the chemical purification and preparation, precautions for yielding high specific activity were particularly stressed. In the first few preliminary runs, the source was prepared by direct deposition of a drop of $CuSO_4$ solution on a collodion film. The deposit tends to crystallize at the edge of the drop and, therefore, forms a non-uniform source.

A more uniform source can be obtained by adding a trace of detergent to the $CuSO_4$ solution or from a colloidal suspension of $Cu(OH)_2$. The source backings used throughout this investigation were thin collodion film of about $4\mu g/cm^2$. The counter window consisted of 5 or 6 layers of collodion film of 3–$4\mu g/cm^2$ each. Auxiliary experiments showed that this counter window should have negligible effects on the electron distribution above 20 kev.

Several runs with sources varying from $0.3\ mg/cm^2$ to $\sim 0.1\ mg/cm^2$ showed a gradual but consistent reduction of deviation *versus* the source thickness at low energy region. Therefore, the importance of preparing extremely thin and uniform sources can never be over emphasized. With the thinnest source ($\sim 0.1\ mg/cm^2$) prepared with the present facilities, the deviation was found to be much less than previously reported.

In comparing the experimental data with the Fermi theory, the Coulomb correction factor has been reexamined and modified. Longmire and Brown[5] recently calculated the screening effect due to atomic electrons and the relativistic effect (which has often been neglected for $Z<29$) for Cu^{64} electrons and positrons. These corrections are considerable for electrons of energies below 200 kev and for positrons of energies below 100 kev (Fig. 1). Applying these corrections, the observed electron distribution (Fig. 1) agrees with the theory from upper energy limit down to $\sim$70 kev. At least part of the remaining discrepancy could very well be due to the finite thickness of the source. The deviation in the case of positron appears to start at a much higher energy $\sim$200 kev (Fig. 1). If these deviations are due to the scattering of electrons or positrons into the low energy region, the effect would be much more pronounced in the case of positrons because there are so few positrons at low energies. This can better be illustrated by comparing the area under the momentum distribution curves (Fig. 2) where the difference between the experimental and theoretical distribution for both positrons and electrons is about 1-2 percent of the total emission, while the previous work[2] reported an excess of 9 percent for positrons and 6 percent for electrons.

In view of the large decrease in the deviation resulting from the use of thinner and more uniform sources and the use of a more rigorous Coulomb correction factor, it seems probable that the remaining small observed deviation is instrumental and the Cu^{64} spectra are actually of the allowed type.

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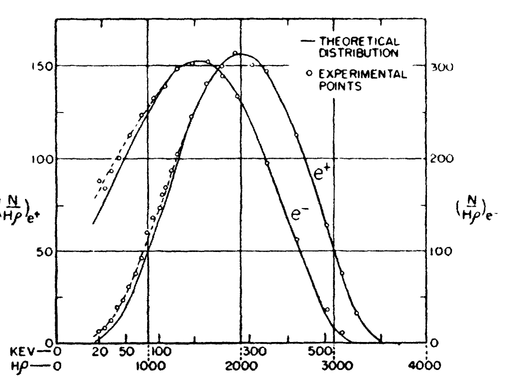

FIG. 2. Momentum spectra of Cu^{64} negatrons and positrons.

Additional Ferromagnetic Resonance Absorption Measuremets on Supermalloy

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November 24, 1948

THE results of a ferromagnetic resonance absorption experiment at 24,050 megacycles on a specimen of annealed Supermalloy were compared with theory[1] in a previous letter.[2] The λ in the relaxation term, $-\lambda[\mathbf{M}-\chi_0\mathbf{H}]$, was assumed constant in this analysis. It is now found that better agreement between theory and experiment is obtained by setting $\lambda\alpha H_z$. Furthermore,

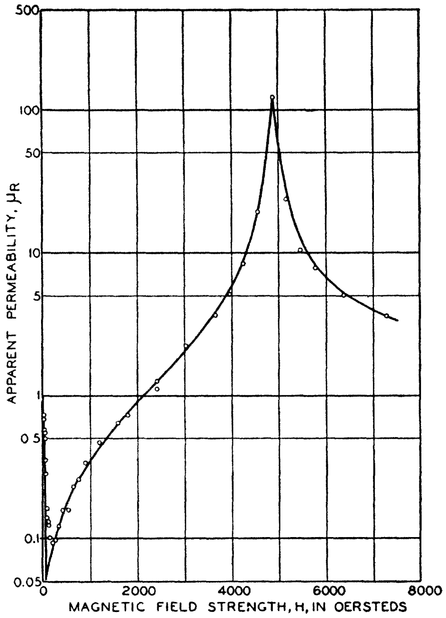

FIG. 1. Ferromagnetic resonance absorption in annealed Supermalloy at 23,900 Mc.

recent and more accurate measurements on Supermalloy[3] disclose a minimum in the μ_R *vs.* H curve at low field strengths, and also confirm the value of $g=2.17$, previously reported.

The test procedure differed but little from that previously described except that the resonant cavity was redesigned to improve the accuracy of the measurements. The test specimen formed the end wall instead of the narrow side walls of the cavity, and was clamped in place to avoid the undesirable soldering operation. Further improvement in accuracy was obtained by adjusting the opening of the symmetrical coupling window. A miniature motor-generator set indicated the static magnetic field strength; the reference magnet for calibrating this device was checked by the Bureau of Standards.

The results of the new measurements are compared with theory in Fig. 1, in which the points represent the experimental data, and the curve shows the theoretical variation with $\lambda/H=2.28\times10^5$ rad./sec.-oersteds. The plotted field values have been corrected for the demagnetizing field of 60 oersteds. The agreement between theory and experiment is very good over the entire range investigated except that the experimental data tend to round off the sharp minimum. The g factor is again found to be 2.17, in agreement with the value previously reported.

These measurements establish the existence of a minimum as well as a maximum in the μ_R *vs.* H curve; this behavior is consistent with theory. The energy dissipation in the ferromagnetic material is proportional to:

$$\mu_R^{\frac{1}{2}}=[(\mu_1^2+\mu_2^2)^{\frac{1}{2}}+\mu_2]^{\frac{1}{2}}.$$

μ_1 and μ_2 are the real and imaginary parts of the r-f permeability. For small damping, $\mu_2\ll1$ at low field strengths. Consequently, $\mu_R<1$ in the approximate range $\mu_1=1$ to $\mu_1=-1$ and will be a minimum when $\mu_1\rightarrow0$. In annealed Supermalloy (Fig. 1), $\mu_R<1$ at fields below 2000 oersteds, is a minimum in the neighborhood of 200 oersteds, and then increases rapidly toward one as $H\rightarrow0$. The resonance equations[1] show that μ_1 has two zero points—one at $\omega\cong\gamma B$ which corresponds to minimum absorption, the other at $\omega\cong\gamma(BH)^{\frac{1}{2}}$ which corresponds to maximum absorption. In principle, one can solve the two zero-point equations simultaneously for γ and $4\pi M_s$. This procedure is not very accurate for the case of Supermalloy since the minimum occurs undesirably close to the demagnetizing field. For the case of nickel, however, the minimum occurs at 1700 oersteds, and the value of $4\pi M_s$ calculated in this way is in good agreement with the accepted value.

In the region where $\mu_R<1$, the material is effectively diamagnetic with respect to the r-f magnetic field and the effective resistivity, $\rho\mu_R$, is less than the d.c. resistivity, ρ. It is, therefore, possible to reduce the effective resistivity of a ferromagnetic metal by the proper application of a relatively weak magnetic field. For the ideal case of no damping, the effective resistivity, the flux density, and the microwave attenuation all decrease to zero, and the skin depth becomes infinite at the minimum.

The effect of cold working a specimen of annealed Supermalloy is shown in Fig. 2; the resonance curve is

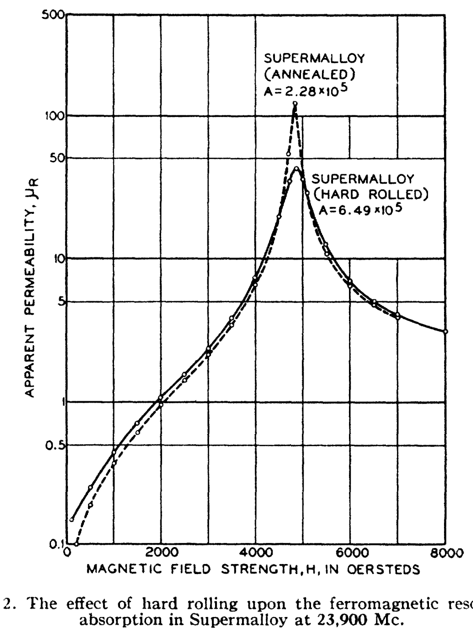

FIG. 2. The effect of hard rolling upon the ferromagnetic resonance absorption in Supermalloy at 23,900 Mc.

broadened ($\lambda/H=6.49\times10^5$ rad./sec.-oersteds) without noticeably altering the g factor when account is taken of the effect of magnetic crystalline anisotropy upon the resonance condition.

I am indebted to Dr. R. M. Bozorth of these Laboratories for his interest and helpful suggestions in connection with this investigation.

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